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Lumbar puncture: Technique, contraindications, and complications in adults

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INTRODUCTION

Lumbar puncture (LP) with examination of cerebrospinal fluid (CSF) is an important diagnostic tool for a variety of infectious and noninfectious neurologic conditions.

The indications, contraindications, technique, and complications of LP in adults will be reviewed here. Techniques of LP in children and of spinal and other types of neuraxial anesthesia are discussed separately. (See "Lumbar puncture in children" and "Spinal anesthesia: Technique" and "Epidural and combined spinal-epidural anesthesia: Techniques".)

Analysis of the CSF is discussed elsewhere. (See "Cerebrospinal fluid: Physiology and utility of an examination in disease states".)

INDICATIONS

LP is essential or extremely useful in the diagnosis of bacterial, fungal, mycobacterial, and viral central nervous system (CNS) infections and, in certain settings, to aid in the diagnosis of subarachnoid hemorrhage (SAH), demyelinating diseases, Guillain-Barré syndrome and other inflammatory disorders, and CNS malignancies.

Urgent — With readily available neuroimaging such as computed tomography (CT) and magnetic resonance imaging (MRI), there are few indications for urgent diagnostic LP.

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However, urgent LP is still indicated to diagnose two serious conditions [1,2]:

- Suspected infectious meningitis or encephalitis.
- Suspected SAH in a patient with a negative CT scan.

The most common use of the LP is to diagnose or exclude meningitis in patients presenting with some combination of fever, altered mental status, headache, or meningismus. Examination of the cerebrospinal fluid (CSF) has a high sensitivity and specificity for determining the presence of bacterial and fungal meningitis. CSF findings in meningitis and encephalitis are discussed separately. (See "Clinical features and diagnosis of acute bacterial meningitis in adults", section on 'Cerebrospinal fluid analysis' and "Aseptic meningitis in adults", section on 'Cerebrospinal fluid' and "Viral encephalitis in adults", section on 'Diagnosis'.)

The presence of blood or xanthochromia in CSF can indicate the presence of subarachnoid bleeding. The analysis of CSF findings in the patient with suspected SAH is discussed in detail separately. (See "Aneurysmal subarachnoid hemorrhage: Clinical manifestations and diagnosis", section on 'Lumbar puncture'.)

Nonurgent — A nonurgent LP is indicated in the diagnosis of many other conditions. Nevertheless, the LP should be performed as soon as is practical. These conditions include:

- Idiopathic intracranial hypertension (pseudotumor cerebri)
- Carcinomatous meningitis
- Normal pressure hydrocephalus
- CNS syphilis
- Leptomeningeal CNS lymphoma
- Autoimmune encephalitis

Conditions in which LP is often a useful component of the diagnostic evaluation:

- Multiple sclerosis
- Guillain-Barré syndrome and chronic inflammatory demyelinating polyneuropathy
- Paraneoplastic syndromes
- Neurosarcoidosis
- CNS vasculitis

LP is also required as a therapeutic or diagnostic maneuver in the following situations:

- Spinal anesthesia
- Intrathecal administration of chemotherapy

- Intrathecal administration of antibiotics
- Injection of contrast media for myelography or for cisternography
- Therapeutic drainage of CSF

CSF findings in these conditions are discussed in individual topic reviews.

CONTRAINDICATIONS AND PRECAUTIONS FOR HIGH-RISK PATIENTS

LP can be safely performed in most circumstances. However, there are specific circumstances when an LP may be contraindicated or precautions should be undertaken to mitigate risks. These clinical scenarios include:

- Suspected raised intracranial pressure (ICP) with risk for cerebral herniation due to obstructive hydrocephalus, cerebral edema, or other space-occupying lesion
- Thrombocytopenia or other bleeding diatheses, including ongoing anticoagulant therapy
- Suspected spinal epidural abscess or skin/soft tissue infection overlying the LP site

Elevated ICP from space-occupying lesion — Patients with elevated ICP from a space-occupying lesion such as an intracranial tumor, abscess, stroke, or obstructive hydrocephalus are at risk of cerebral herniation. In these patients, an LP can precipitate herniation, a rare but often fatal complication. (See 'Cerebral herniation' below.)

For patients with suspected elevated ICP, we suggest urgent neuroimaging, typically with a head CT, as a prerequisite for LP to assess for the presence of a space-occupying lesion. (See 'Indications for CT scan' below.)

LP is generally contraindicated in patients with elevated ICP due to the presence of a space-occupying lesion. However, published cases exist of patients with imaging evidence of space-occupying lesions and brain edema safely undergoing LP [3]. The risk of performing an LP in these patients should be weighed carefully against potential benefits, and treatment to reduce elevated ICP may be warranted. (see "Evaluation and management of elevated intracranial pressure in adults", section on 'Urgent situations').

Indications for CT scan — We suggest performing a noncontrast head CT before an LP to identify a possible mass lesion and other causes of increased ICP for patients with the following clinical risk factors:

- Altered mentation

- Focal neurologic signs or symptoms
- Papilledema
- New seizure
- Suspected metastatic cancer
- Immunocompromised state

Limited data are available to identify clinical factors associated with a risk for herniation after LP. A 1969 study of 30 patients who had clinical features associated with increased ICP attempted to identify factors associated with neurologic deterioration after LP [4]. The most common findings on preprocedural examination were focal findings on neurologic examination (including dysphagia, hemiparesis, and cranial nerve palsies) (73 percent) and papilledema (30 percent). Deterioration occurred immediately in one-half of the patients, with the remainder declining within 12 hours. In contemporary practice, CT-based neuroimaging is widely available and readily used for patients with clinical risk factors for mass lesions, likely reducing the likelihood that an LP would be performed without imaging in such patients.

Imaging should be reviewed to assess for findings suggestive of elevated ICP from a mass lesion.

- **CT findings in patients with elevated ICP** – Mass lesions causing elevated ICP are usually easily identified on CT scan (image 1). Features include distortion of symmetry and midline structures, compression of ventricles, and the presence of a visible mass lesion. However, the CT scan should also be scrutinized for more subtle signs of mass effect or cerebral edema including loss of differentiation between gray and white matter, effacement of sulci or basal cisterns, and ventricular enlargement [5].
- **Role of brain MRI** – Brain MRI with contrast may be performed as an alternative neuroimaging test to exclude a space-occupying lesion but is typically less readily available than CT and is a longer study to perform than CT. Brain MRI prior to an LP is generally reserved as a follow-up study for circumstances when the acuity or significance of abnormal findings on head CT is uncertain.

However, the ability of imaging findings to predict patients at risk for herniation after an LP is modest. In a series that assessed the association between a radiologic contraindication and deterioration after LP, interrater reliability regarding the presence of a presumed contraindication on CT was only moderate (kappa = 0.47) [6]. The overall rate of

deterioration following LP was 3.1 percent (47 patients), and the proportion of patients with an imaging contraindication who deteriorated after LP was similar to the proportion of those without such a contraindication (14 versus 11 percent). In another study of 301 adults with suspected meningitis, among 96 patients who underwent head CT before LP but had no abnormal clinical features suggestive of elevated ICP, only three had an abnormal CT scan [7]. One of the three patients had a mild mass effect, but all three underwent LP without herniation. By contrast, cases of brain herniation after LP have been reported even in patients without abnormalities on head CT [8,9].

For other patients without risk factors for an intracranial space-occupying lesion, head CT prior to LP may be unwarranted or even harmful [7,10]. Screening neuroimaging for such patients with an urgent indication for LP (eg, suspected bacterial meningitis) delays the performance of LP, which in turn may delay treatment or limit the diagnostic power of cerebrospinal fluid (CSF) analysis when performed after antibiotic administration. In a study of adults with suspected meningitis, patients who underwent CT scan before LP had an average of a two-hour delay in diagnosis and a one-hour delay in therapy.

Bleeding diathesis — We generally advise **not** performing an LP in patients with coagulation defects who have severe thrombocytopenia (eg, platelet count <50,000 to 80,000/microL), an international normalized ratio (INR) >1.4, or are receiving anticoagulation, without correcting the underlying abnormalities [11,12].

However, the relative risk of performing an LP should be weighed against the potential benefit (eg, diagnosing meningitis due to an unusual or difficult-to-treat pathogen, identifying subarachnoid hemorrhage [SAH] as the cause of a thunderclap headache). In select cases in which LP is considered necessary despite a high risk of bleeding, it may be useful to perform the procedure under fluoroscopy, which may reduce the incidence of traumatic tap [13].

- **Managing anticoagulant and antiplatelet medication** – The management of antithrombotic medications for patients with an indication for an LP varies according to the urgency of the LP, the bleeding risk associated with the agent, and the thromboembolic risk associated with stopping the medication [14-17].
    - **Urgent need for LP** – For patients with an urgent indication for LP who are receiving anticoagulant medications, we administer medications to reverse the anticoagulant prior to performing an LP (table 1 and table 2). (See "Management of warfarin-associated bleeding or supratherapeutic INR", section

on 'Urgent surgery/procedure' and "Management of bleeding in patients receiving direct oral anticoagulants", section on 'Anticoagulant reversal'.)

- **Nonurgent need for LP** – For those with a nonurgent indication, we temporarily withhold anticoagulant dosing without reversal and perform the LP after the anticoagulant effect has dissipated, when the risk of interrupting therapy is not high (table 3). Bridging with shorter-acting parenteral anticoagulant therapy may be used to shorten the duration of interrupting anticoagulation for patients at high risk of thromboembolism (table 4). (See "Perioperative management of patients receiving anticoagulants".)

  In addition, we also stop antiplatelet therapy (eg, thienopyridine derivatives [clopidogrel, ticlopidine, prasugrel, ticagrelor], glycoprotein (GP) IIb/IIIa inhibitors) or multiple antithrombotic agents, if possible. The time interval between stopping antiplatelet therapy and performing an LP varies according by pharmacokinetic properties of the agent(s) (table 3).

  The timing of performing neuraxial procedures after withholding anticoagulant and antiplatelet medications is discussed in detail separately and appears in tables (table 3 and table 5). (See "Neuraxial anesthesia/analgesia techniques in the patient receiving anticoagulant or antiplatelet medication".)

- **Resuming anticoagulation after LP** – The optimal timing of restarting anticoagulation after LP varies by specific agent, route of administration, and urgency of anticoagulation resumption. The timing of resumption may be additionally delayed after a traumatic LP to permit complete hemostasis and reduce the risk of developing a spinal hematoma (table 3 and table 5). (See "Neuraxial anesthesia/analgesia techniques in the patient receiving anticoagulant or antiplatelet medication" and 'Identifying a traumatic tap' below.)

- **Patients with an unknown cause of coagulopathy** – When an LP is considered urgent and essential in a patient with an abnormal INR or platelet count in whom the cause is not obvious, consultation with a hematologist may provide the best advice for safe correction of the coagulopathy prior to performing the LP. In one series, 37 patients anticoagulated with vitamin K antagonists received prothrombin complex concentrate prior to emergency LP; INR reversal was successful in 33 patients within a median 135 minutes; however, two patients experienced a thromboembolic event (stroke, myocardial infraction), and one clinically irrelevant intracranial subdural

hematoma developed [18], suggesting that risks and benefits should be carefully assessed in individual patients. (See "Approach to the adult with a suspected bleeding disorder".)

Spinal epidural abscess and other infections — An LP through a spinal epidural abscess can result in the spread of bacteria into the subarachnoid space. The risk of intrathecal spread of infection applies to lesions in the cervical and thoracic regions along with those in lumbar regions because longitudinal extension is common with spinal epidural abscesses. Because an LP is not needed for diagnosis, the procedure should **not** be performed in most patients with suspected epidural abscess [19]. (See "Spinal epidural abscess".)

We **avoid** LP for patients with skin or soft tissue infection overlying the LP site, due to the risk of intrathecal spread of infection.

Bacteremia is **not** a contraindication to LP. Because meningitis can be caused in animals by performing an LP after first inducing a bacteremia [20,21], some authors have speculated that an LP in a bacteremic patient without preexisting meningitis might actually cause meningitis [22]. However, this phenomenon is rare, if it occurs at all. In a retrospective study of 1089 infants with bacteremia, the incidence of subsequent meningitis in children who underwent LP was similar to the incidence of meningitis among those who did not undergo LP (2.1 versus 0.8 percent) [23]. We and other authors believe that theoretical concerns about inducing meningitis in patients with bacteremia should not be used as the basis to forego LP if meningitis is suspected [24].

Blood cultures should be obtained, and antimicrobial therapy started promptly, if an LP is unable to be performed or is delayed in bacteremic patients with suspected meningitis. (See "Clinical features and diagnosis of acute bacterial meningitis in adults", section on 'If LP is delayed or deferred'.)

TECHNIQUE

Positioning — LP can be performed with the patient in the lateral decubitus, sitting, or prone positions.

- For most patients, we use the lateral decubitus position as it facilitates access to the cerebrospinal fluid (CSF) space and permits an accurate measurement of intraspinal opening and closing pressures.

- The sitting position may be preferred in cases when identifying the midline and bony landmarks is difficult, such as for selected patients with obesity or prior back surgery as well as for patients unable to tolerate the lateral decubitus position.

  The sitting position is typically used for LP when measuring opening and closing pressures are not required. Seated patients can be carefully turned to the lateral decubitus position to measure pressures after the needle has been inserted into the spinal canal, but doing so may increase the risk of post-LP headache or other complications. Turning patients after needle insertion should be reserved for rare circumstances when pressure measurement is required and an LP in the lateral decubitus position is unsuccessful and fluoroscopic guidance is unavailable.

- The prone position is usually used for LPs performed with fluoroscopic guidance. (See 'Imaging guidance' below.)

Correct patient positioning is an important determinant of success in obtaining CSF. In the lateral decubitus position, the patient should be instructed to assume the fetal position with the neck, back, and limbs held in flexion (figure 1). Flexing the spine opens the space for needles insertion between the spinous processes (figure 2). The patient should be positioned with the back close to and parallel to the edge of the bed or examining table. The hips should be aligned one above the other and legs parallel to each other. Pillows placed under the head and between the knees may improve body alignment and patient comfort.

Determining the needle insertion site — The highest points of the iliac crests should be identified visually and confirmed by palpation; a direct line joining these is a guide to the fourth lumbar vertebral body. However, this line may intersect the spine at points ranging from L1-L2 to L4-L5 [25] and tends to indicate a higher spinal level in females and in patients with obesity [26]. The lumbar spinous processes of L3, L4, and L5, and the interspaces between, can usually be directly identified by palpation.

The spinal needle can be safely inserted into the subarachnoid space at the L3-4, L4-5, or L5-S1 interspaces since they are below the termination of the spinal cord in most patients (figure 3). Imaging guidance may be warranted for other patients with abnormalities of the spinal cord. (See "Closed spinal dysraphism: Clinical manifestations, diagnosis, and management".)

Spinal cord imaging is not necessary for most patients prior to LP, but, if performed, images should be reviewed to confirm the position of the conus and identify the most

accessible safe interspace. Ultrasound can be used to determine the correct needle insertion site by counting interspaces up from the sacrum. The role of ultrasound for neuraxial procedures is discussed separately. (See "Ultrasound guidance for neuraxial anesthesia techniques", section on 'Accuracy in identifying intervertebral levels'.)

Aseptic technique — The overlying skin should be cleaned with alcohol and a disinfectant such as povidone-iodine or chlorhexidine (0.5 percent in 70 percent alcohol). Many product inserts of chlorhexidine-containing solutions warn against use of chlorhexidine prior to LP because of a concern that it can cause arachnoiditis. The evidence that it does so is very limited [27] and chlorhexidine has an advantage over povidone-iodine in its faster onset, superior efficacy, and greater potency [28-32]. The incidence of neurologic complications following chlorhexidine skin antisepsis for spinal anesthesia appears to be very low. In a retrospective study of 11,095 patients who underwent spinal anesthesia with chlorhexidine skin antisepsis, neurologic complications associated with the spinal procedure occurred in only five patients, corresponding to an incidence of 0.04 percent [33]. None of the complications were due to arachnoiditis.

After the skin is cleaned and allowed to dry, a sterile drape with an opening over the lumbar spine is placed on the patient.

We suggest a face mask be used for LP. While evidence that face masks prevent infection is very limited, the burden of wearing a mask is negligible. Cases of meningitis involving bacteria found in normal mouth flora have occurred following LP or spinal anesthesia performed by a clinician who did not wear a mask for the procedure [34]. While routine use of face masks during diagnostic LP and neuroradiologic imaging procedures involving LP has been recommended by some [35-37], others question the practicality and necessity of the use of face masks since infections are rare and there is no proof that face masks prevent such infections [24,38]. The Healthcare Infection Control Practices Advisory Committee and the Centers for Disease Control and Prevention (CDC) recommend face masks for individuals who place a catheter or inject material into the spinal canal [39,40]. (See "Infection prevention: Precautions for preventing transmission of infection".)

Equipment — Disposable spinal kits are frequently used for LP. Kits typically contain needles, a local anesthetic agent, a fenestrated drape, manometer with stopcock, and collecting tubes. Other required equipment for LP may include antiseptic solution such as chlorhexidine.

Spinal needles are manufactured with different needle tips (cutting versus atraumatic) (

figure 4) and bore sizes. These features can influence both the risk of complications and the technical difficulty of the procedure. We recommend using atraumatic needles over cutting needles when available. The risk of post-LP headache is lower with atraumatic (pencil point) needles compared with cutting needles as well as with smaller-bore (eg, 20 or 22 gauge) cutting needles compared with larger-bore cutting needles. However, the risk of post-LP headache does not appear higher with larger-bore atraumatic needles. Cutting needles are typically easier to insert than atraumatic needles. Larger-bore needles are easier to handle and provide rapid pressure transduction and optimal flow rate for diagnostic LP. These issues are discussed in detail separately. (See "Post dural puncture headache", section on 'Prevention of PDPH after dural puncture'.)

Procedure — After positioning the patient optimally, perform the LP as follows:

- Palpate the interspace between two spinous processes at the chosen spinal level. (See 'Determining the needle insertion site' above.)
- With a 25-gauge needle, infiltrate the skin and subcutaneous tissue with local anesthetic (eg, 1 percent lidocaine) in the midline, in the lower third of the interspace.
- Insert a styleted 20- or 22-gauge spinal needle at a slightly cephalad angle. If a cutting tip needle is used, insert the needle with the bevel parallel to the long axis of the spine to reduce the risk of postdural puncture headache (PDPH) [41]. (See "Post dural puncture headache", section on 'Procedural risk factors'.)
- Advance the needle slowly, passing through the ligamentum flavum, followed by the epidural space, and then the dura-arachnoid (figure 5). Changes in resistance may be felt as the needle passes through each of these layers, and a pop is often felt when the dura is pierced (figure 5). Advance the needle incrementally, removing the stylet periodically to check for CSF flow, reinserting the stylet for each advancement [42]. The depth of the dura from the skin in patients of typical body habitus is 5.1±1.0 cm and may be longer in patients with obesity [43,44].

  If the needle tip hits bone and there is no CSF flow, withdraw the needle slightly and recheck for CSF. If still no flow, replace the stylet and withdraw the needle most of its length before redirecting the needle along a new trajectory. Then reinsert the needle slowly, removing the stylet periodically to check for CSF flow. If blood-tinged CSF appears, it should usually clear unless there is subarachnoid hemorrhage (SAH). (See 'Identifying a traumatic tap' below.)

Some authors report a higher rate of successful LP when the stylet is removed just after the skin is punctured and before it is passed into the subarachnoid space in order to better observe the flow of CSF upon entry of the subarachnoid space [45,46]; however, this technique may be associated with a risk of infection, failure to get flow of CSF, and the risk of the development of an epidermoid tumor. (See 'Epidermoid tumor' below.)

- Once CSF flows well from the needle hub, advance the needle no further.
- Measure opening pressure with the patient in the lateral decubitus or prone position. Opening pressure does not appear to be significantly different if measured in the prone or lateral decubitus position [47].

  For patients in the lateral decubitus position, ask the patient to slowly straighten the legs to allow free flow of CSF and avoid transmitting intraabdominal pressure to the thecal space. While the pressure measurement is affected by the position of the legs, most [48-51], but not all [52,53], studies suggest that effect is likely to be small. In one review, pressures were elevated by only 1 to 2 cm H_2O in most studies studying this effect; however, in one study, changing position from a straight to a fully flexed position resulted in an increase in pressure of 6.4 mmHg (approximately 8.7 cm H_2O) [48].

  Attach the manometer to the hub of the spinal needle with a three-way stopcock. Allow the CSF to rise within the column of the manometer. Record peak measurement as opening pressure then turn the stopcock to drain the CSF from the manometer into the collection tube.
- After removing the manometer, allow CSF to flow by gravity into sterile plastic tubes. Do not aspirate CSF, as this may increase the risk of bleeding [42,54]. Typically, 8 to 16 mL of CSF is collected (2 to 4 mL in each of four tubes) and sent for analysis; however, higher volumes may be collected to increase diagnostic yield in certain circumstances, such as for patients with suspected carcinomatous, mycobacterial, or fungal meningitis, and those with normal pressure hydrocephalus.
- The stylet may be replaced before removing the spinal needle. Whether this reduces the risk of PDPH, particularly with atraumatic needles, is unclear. This issue is discussed separately. (See "Post dural puncture headache", section on 'Procedural risk factors'.)

A paramedian insertion is an alternate approach for LP for patients with difficult anatomy. A paramedian insertion through the L5-S1 space (Taylor approach) (figure 6) has been successfully used in a patient with advanced ankylosing spondylitis [55]. The technique for paramedian insertion of a spinal needle is described separately and is shown in a figure (figure 6). (See "Spinal anesthesia: Technique", section on 'Paramedian approach technique'.)

Imaging guidance — Imaging guidance with fluoroscopy or ultrasound is typically used for patients with difficult anatomy and/or unsuccessful LP attempts. Imaging-guided LPs may also be useful for patients with obesity or who have difficult anatomy (eg, due to prior spine surgery or history of spinal dysraphism).

- **Fluoroscopy** – Most neuroradiologists perform fluoroscopically guided LPs in the L2-L3 or L3-L4 intervertebral space with the patient in the prone position [56]. In addition to improving success rates, fluoroscopic guidance may reduce the incidence of traumatic LP [13].
- **Ultrasound** – Ultrasound guidance can be used to determine the best needle path or interspace, as well as to identify the desired spinal level (eg, L3-4, L4-5, L5-S1) [57,58]. A randomized trial involving 100 adult patients undergoing LP in the emergency department found no significant difference in outcomes with ultrasound guidance compared with a conventional landmark based technique [59].

When used for neuraxial anesthesia, ultrasound guidance may reduce the risk of failed block, traumatic procedures, and number of needle insertions in some patient populations, though the evidence is inconsistent. This is discussed separately. (See "Ultrasound guidance for neuraxial anesthesia techniques", section on 'ultrasound guidance versus landmark based neuraxial techniques'.)

COMPLICATIONS

LP is a relatively safe procedure, but minor and major complications can occur even when standard infection control measures and good technique are used. These complications include:

- Infection
- Bleeding
- Post-LP headache

- Intracranial hypotension
- Cerebral herniation
- Cerebral vasoconstriction and encephalopathy syndromes
- Pneumocephalus
- Radicular or back pain
- Late onset of epidermoid tumors of the thecal sac

The risk of complications was studied in a cohort of 376 patients who underwent LP for evaluation of acute cerebrovascular disease [60]. The following frequency of complications was noted: backache (25 percent), headache (22 percent), headache and backache (12 percent), severe radicular pain (15 percent), and paraparesis (1.5 percent). Severe pain or paraparesis occurred in 6.7 percent of patients receiving anticoagulants following the procedure and in none of the 34 patients who did not receive anticoagulants. In other studies, transient headache was the most common symptomatic complication, occurring in 11 to 70 percent of patients with other complications occurring in less than 1 percent [24,61,62].

Infection — Infections are rare after LP with the use of standard aseptic technique. (See 'Aseptic technique' above.)

Meningitis is an uncommon complication of LP. In a review of 179 cases of post-LP meningitis reported in the medical literature between 1952 and 2005, half of all cases occurred after spinal anesthesia; only 9 percent occurred after diagnostic LP. The most commonly isolated causative organisms were *Streptococcus salivarius* (30 percent), *Streptococcus viridans* (29 percent), alpha-hemolytic streptococcus (11 percent), *Staphylococcus aureus* (9 percent), and *Pseudomonas aeruginosa* (8 percent) [63].

While some cases of post-LP meningitis due to staphylococci, pseudomonas, and other gram-negative bacilli have been attributed to contaminated instruments or solutions or poor technique [64], other studies have suggested that post-LP meningitis could arise from aerosolized oropharyngeal secretions from personnel present during the procedure, especially since many of the causative organisms are found in the mouth and upper airway [38,63,65,66]. (See 'Aseptic technique' above.)

There are rare case reports of discitis and vertebral osteomyelitis following LP. Most cases were due to normal skin flora such as *Cutibacterium* species and coagulase-negative staphylococci [67-69]. These complications presumably result from direct inoculation of bacteria into the vertebral bone.

Bleeding — Cerebrospinal fluid (CSF) is normally acellular, although up to five red blood cells (RBCs)/microL are considered normal after LP. Higher RBC counts or visible blood in the CSF sample indicate bleeding. Blood in the CSF sample may be seen in the setting of procedural trauma or from an intra-axial source of bleeding such as subarachnoid hemorrhage (SAH). Bleeding from a traumatic tap is frequently minor and may be managed conservatively, but prolonged bleeding can result in a spinal epidural hematoma that may cause nerve injury or paralysis.

Identifying a traumatic tap — Minor bleeding that contaminates the CSF sample due to needle trauma occurs in more than 70 percent of diagnostic LPs [70], especially with procedures that require multiple needle insertions, patients with difficult anatomy, and in the setting of a bleeding diathesis. However, an intra-axial source of bleeding may also be present.

Features suggestive of an intra-axial source of bleeding rather than a traumatic LP include:

- No clearing of blood with successive CSF collection tubes
- Elevated white blood cell-to-red blood cell ratio in the CSF compared with peripheral blood sample
- Presence of xanthochromia (if suspected bleeding source onset >2 hours prior)

Specific features to discriminate a traumatic tap are discussed in greater detail separately. (See "Cerebrospinal fluid: Physiology and utility of an examination in disease states", section on 'Cells' and "Aneurysmal subarachnoid hemorrhage: Clinical manifestations and diagnosis", section on 'Findings in SAH'.)

Spinal epidural hematoma — Serious bleeding that results in spinal cord or cauda equina compromise is rare in the absence of bleeding risk [71]. A 2016 literature review identified 35 published cases of spinal epidural hematoma occurring after LP [72]. Patients who have thrombocytopenia or other bleeding disorders or those who received anticoagulant therapy prior to or immediately after undergoing LP have an increased risk of bleeding. In one series, spinal hematoma developed in 7 of 342 patients (2 percent) who received anticoagulant therapy after undergoing LP; five of these patients developed paraparesis [60]. In one literature review, 47 percent of 21 published cases of spinal hematoma following LP occurred in patients with a coagulopathy [73]. Thus, a high index of suspicion of spinal hematoma should be maintained in all patients who develop neurologic symptoms after an LP, including those with no known coagulopathy. The risk of developing a spinal epidural hematoma after LP may be further increased with other

factors that increase bleeding risk, such as traumatic or repeated taps.

The diagnosis of spinal hematoma is complicated by the concealed nature of the bleeding; thus, a high index of suspicion must be maintained. Patients who have persistent back pain or neurologic findings (eg, weakness, decreased sensation, or incontinence) after undergoing LP require urgent evaluation (usually spinal MRI) for possible spinal hematoma [74].

The appropriate treatment for patients with significant or progressing neurologic deficits is prompt surgical intervention, usually a laminectomy, and evacuation of the blood. Timely decompression of the hematoma is essential to avoid permanent loss of neurologic function [75,76]. Patients with mild symptoms or early signs of recovery may be managed conservatively with vigilant monitoring; dexamethasone may be administered to mitigate neurologic injury [73,77]. (See "Disorders affecting the spinal cord", section on 'Spinal epidural hematoma'.)

Post-LP headache — Headache, which occurs in 10 to 70 percent of patients, is one of the most common complications following LP. Post-LP headache is caused by leakage of CSF from the dura and traction on pain-sensitive structures. Patients characteristically present with frontal or occipital headache within 24 to 48 hours of the procedure, which is exacerbated in an upright position and improved in the supine position. Associated symptoms may include nausea, vomiting, dizziness, tinnitus, and visual changes.

This risk factors, prevention, and treatment of post-LP headache are discussed separately. (See "Post dural puncture headache".)

Other syndromes related to intracranial hypotension — In addition to post-LP headache, several other neurologic conditions may also rarely occur following an LP. Cranial nerve dysfunction, subdural hematoma, and cerebral venous thrombosis are uncommon post-LP complications typically attributed to intracranial hypotension from CSF leakage. Intracranial hypotension leads to traction or compression of intracranial structures such as cranial nerves, dural bridging veins, and venous sinuses. (See "Spontaneous intracranial hypotension: Pathophysiology, clinical features, and diagnosis", section on 'Pathophysiology'.)

Cranial nerve dysfunction

- **Diplopia** – Horizontal diplopia may occur from ocular misalignment due to an abducens nerve (cranial nerve VI) palsy. Both unilateral and bilateral abducens palsy

are reported complications of LP [78-80]. Abducens nerve palsies after LP are generally accompanied by other clinical features of post-LP headache. Most patients recover completely within days to weeks.

Rare cases of diplopia due to oculomotor (cranial nerve III) palsy and combined abducens and trochlear nerve (cranial nerve IV) palsy have also been reported [81,82].

- **Hearing loss** – Hearing loss may occur after dural puncture and has been variably reported in 10 to 50 percent of patients after spinal anesthesia, though less than 25 percent of these patients are aware of the deficit [83,84]. It may be unilateral or bilateral and may occur even in the absence of headache. Hearing loss is usually transient, but there are reported cases of hearing loss lasting for years after spinal anesthesia [85], unintentional dural puncture (UDP) [86], and diagnostic LP [87]. Although the mechanism is unproven, hearing loss may be due to traction of the vestibulocochlear nerve (cranial nerve VIII) from intracranial hypotension. In small studies, larger needle size [88] and cutting needles have been associated with increased incidence of hearing loss [89]. Epidural blood patch (EBP) has been performed with resolution of hearing loss [87].

Subdural hematoma — Cranial subdural hematoma may rarely occur following LP due to rupture of dural bridging veins resulting from intracranial hypotension. Large retrospective cohort studies have found an association between LP and increased risk of subdural hematoma [90-95]. (See "Subdural hematoma in adults: Etiology, clinical features, and diagnosis", section on 'Intracranial hypotension'.)

Subdural hematoma may present with headache, similar to symptoms of post-LP headache. However, post-LP headaches are typically positional, occurring with sitting or standing up and improving or resolving with recumbency. Subdural hematoma may cause a nonpositional headache sometimes also associated with nausea, vomiting, neck pain, or focal neurologic symptoms (eg, hemiparesis). In a cohort of more than 22 million patients who received neuraxial anesthesia for childbirth, the rate of subdural hematoma was lower than post-LP headache (1.5 versus 309 per 100,000 patients) [93].

The evaluation and management of subdural hematoma is discussed separately. (See "Subdural hematoma in adults: Management and prognosis".)

Hematoma in the spinal subdural space may also occur as a bleeding complication of LP [96-98]. Neurosurgical evacuation may be warranted for patients with a spinal subdural

hematoma due to the risk of permanent neurologic injury from cauda equina syndrome [72]. (See "Anatomy and localization of spinal cord disorders", section on 'Cauda equina syndrome'.)

Cerebral venous thrombosis — Cerebral venous thrombosis may occur after LP as a severe complication of intracranial hypotension and brain sagging, typically in the setting of other complications such as post-LP headache and/or subdural hematoma [99,100]. Retrospective cohort studies have identified an independent association between LP and cerebral venous thrombosis [94,101,102]. In one retrospective cohort study of over 1 million patients who received neuraxial anesthesia for childbirth, 4800 of whom developed postdural puncture headache (PDPH), the incidence of a composite of subdural hematoma and cerebral venous thrombosis was significantly higher in patients who had a PDPH, compared with those who did not (0.3 versus 0.02 percent) [94]. (See "Cerebral venous thrombosis: Etiology, clinical features, and diagnosis".)

Cerebral herniation — The most serious complication of LP is cerebral herniation. Cardiorespiratory collapse, loss of consciousness, and death may follow. Suspected increased intracranial pressure (ICP) due to an intracranial mass lesion, cerebral edema, or obstructive hydrocephalus is a relative contraindication to performance of an LP and also requires independent assessment and treatment. (See 'Elevated ICP from space-occupying lesion' above.)

The magnitude of the risk of herniation was evaluated in a 1959 report of 129 patients with increased ICP who underwent LP: 15 patients (12 percent) had an unfavorable outcome within 48 hours of LP [103]. Similar findings were noted in a series of 55 patients with SAH: seven patients (13 percent) experienced neurologic deterioration during or soon after an LP, six of whom had evidence of cerebral herniation [104]. In another series of 1533 patients with acute bacterial meningitis, 47 (3 percent) had a clinical deterioration after LP [6]. However, determining the role of the LP in these outcomes can be difficult in such patients at risk of herniation due to SAH or other cerebral conditions that cause elevated ICP. (See "Evaluation and management of elevated intracranial pressure in adults".)

Other uncommon cerebrovascular syndromes — In rare cases, dural puncture has been associated with other cerebrovascular conditions including:

- Reversible cerebral vasoconstriction syndrome (RCVS) [105,106]
- Posterior reversible encephalopathy syndrome (PRES) [107-109]
- Subarachnoid and intraventricular hemorrhage [77,110]

Causation for these events is uncertain; some of these reports involved obstetric patients with possible preeclampsia or eclampsia, which are also associated with RCVS and PRES.

Radicular symptoms and low back pain — It is not uncommon (13 percent in one series) for patients to experience transient electrical-type pain in one leg during the procedure [61]. However, sustained radicular symptoms or radicular injury appear to be rare [111].

Up to one-third of patients complain of localized back pain after LP; this may persist for several days, but rarely may be persistent [61]. Among patients with post-LP headache, chronic back pain does not appear to be associated with the use of an EBP [112,113].

Epidermoid tumor — The formation of an epidermoid spinal cord tumor is a rare complication of LP that may become evident years after the procedure is performed. Most reported cases are in children ages 5 to 12 years who had an LP in infancy; however, this has also been described in adults [114-116]. It may be caused by epidermoid tissue that is transplanted into the spinal canal during LP without a stylet or with one that is poorly fitting. This complication probably can be avoided by using spinal needles with tight-fitting stylets during LP [117,118].

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Post dural puncture headache".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to

print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topic (see "Patient education: Lumbar puncture (spinal tap) (The Basics)" and "Patient education: Spinal headache (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Indications** – LP is essential or extremely useful in the diagnosis of bacterial, fungal, mycobacterial, and viral central nervous system (CNS) infections and in the diagnosis of subarachnoid hemorrhage (SAH) not seen on head CT. LP is also helpful in the diagnostic evaluation of several other conditions including CNS malignancies, demyelinating diseases, Guillain-Barré syndrome, idiopathic intracranial hypertension, and CNS vasculitides. (See 'Indications' above.)
- **Contraindications** – LP can be safely performed in most circumstances. Specific circumstances in which an LP may be contraindicated or precautions should be undertaken to mitigate risks include the following (see 'Contraindications and precautions for high-risk patients' above):
  - Possible raised intracranial pressure (ICP) with risk for cerebral herniation due to obstructive hydrocephalus, cerebral edema, or space-occupying lesion
  - Thrombocytopenia (eg, platelet counts <50,000 to 80,000/microL), an international normalized ratio (INR) >1.4, or other bleeding diatheses, including ongoing anticoagulant therapy
  - Suspected spinal epidural abscess or skin/soft tissue infection overlying the LP site
- **Preprocedural evaluation and management for high-risk patients**
  - **Suspected elevated ICP** – For patients with suspected elevated ICP (altered mentation, focal neurologic signs or symptoms, papilledema, new seizure, suspected metastatic cancer, immunocompromised state) due to a space-occupying lesion, we suggest performing a head CT as a prerequisite for LP to exclude a space-occupying lesion (**Grade 2C**). (See 'Indications for CT scan' above.)
  - **Coagulopathy** – The management of antithrombotic medications for patients with an indication for an LP varies according to the urgency of the LP, the bleeding risk associated with the agent, and the thromboembolic risk associated with

stopping the medication. (See 'Bleeding diathesis' above.)

- For patients with an urgent indication for LP who are receiving anticoagulant medications, we administer medications to reverse the anticoagulant prior to performing an LP (table 1 and table 2).
- For those with a nonurgent indication, we temporarily withhold anticoagulant dosing without reversal and perform the LP after the anticoagulant effect has dissipated, when the risk of interrupting therapy is not high (table 3). Bridging with shorter-acting parenteral anticoagulant therapy may be used to shorten the duration of interrupting anticoagulation for patients at high risk of thromboembolism (table 4).
- We stop antiplatelet therapy (eg, thienopyridine derivatives [clopidogrel, ticlopidine, prasugrel, ticagrelor], glycoprotein (GP) IIb/IIIa inhibitors), or multiple antithrombotic agents, if possible.

- **Technique** – The technique is described briefly here and in more detail above. (See 'Technique' above.)
  - We typically perform an LP with the patient in the lateral decubitus position to facilitate access to the cerebrospinal fluid (CSF) space and permit accurate measurement of intraspinal pressures (figure 1). An LP can also be performed with the patient in the prone positions or sitting upright. (See 'Positioning' above.)
  - The site of needle insertion is determined using surface landmarks. The spinal needle can be inserted into the subarachnoid space at the L3-4, L4-5, or L5-S1 interspaces. (See 'Determining the needle insertion site' above.)
  - LP should be performed with aseptic technique. The overlying skin should be cleaned with alcohol and a disinfectant such as povidone-iodine or chlorhexidine. We suggest using a face mask when performing LP. (See 'Aseptic technique' above.)
  - Atraumatic needles are preferred over cutting needles when available as they may reduce the risk of post-LP headache (figure 4). (See 'Equipment' above and "Post dural puncture headache", section on 'Procedural risk factors'.)
  - The styleted spinal needle is inserted at a slightly cephalad angle and advanced incrementally, removing the stylet periodically to check for CSF flow, reinserting the stylet for each advancement (figure 5). Once the needle has reached the

subarachnoid space and CSF begins to flow, opening pressure is measured with the patient in the lateral decubitus or prone position. Then, a total of 8 to 15 mL of CSF is collected for analysis. (See 'Procedure' above.)

Imaging guidance with fluoroscopy or ultrasound is typically reserved for patients with difficult anatomy and/or unsuccessful LP attempts. (See 'Imaging guidance' above.)

- **Complications** – LP is a relatively safe procedure, but minor and major complications can occur even when standard infection control measures and good technique are used. Common complications include (see 'Complications' above):
  - Infection
  - Bleeding
  - Post-LP headache

  Other uncommon complications of LP include neurologic deficits due to intracranial hypotension, cerebral herniation, cerebral vasoconstriction and encephalopathy syndromes, subarachnoid and intraventricular hemorrhage, radicular or back pain, and late onset of epidermoid tumors of the thecal sac.

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